

Results of plate element runs Dec 2005

In order to check the various plate elements (QUAD4 and TRIA3 Mindlin elements, QUAD4K and TRIA3K Kirchhoff elements) several test runs were made. Appendices A-1 through A-4 and B-1 through B-4 show the results. All of the runs are for a 2"x2" square plate with only $\frac{1}{4}$ of the plate modeled due to symmetry. Two plate thicknesses were analyzed (0.02" thin plate and 0.20" thick plate). The plates were subjected to two sets of loadings in each of two sets of boundary conditions:

- Simply supported plate subjected to:
 - uniform pressure load and
- Stress-free plate (supported in rigid body mode only) subjected to:
 - constant bulk temperature change and
 - temperature gradient through the plate thickness

The plate physical and material properties were:

- Length and width = 2.0"
- $E = 10.9 \times 10^6$
- $G = 4.19 \times 10^6$
- Poissons ratio = 0.3
- Pressure load = 0.05 lb/in²

The following is a key to the tables in the appendices:

- Appendices A-1 through A-4 are results when the QUAD4 element is the original element (MIN4) with:
 - App A-1: Simply supported 0.02" thick plate with pressure load
 - App A-2: Simply supported 0.20" thick plate with pressure load
 - App A-3: Stress-free 0.02" thick plate with bulk and gradient thermal load
 - App A-4: Stress-free 0.20" thick plate with bulk and gradient thermal load
- Appendices B-1 through B-4 are results when the QUAD4 element is the new element (MIN4T) with:
 - App B-1: Simply supported 0.02" thick plate with pressure load
 - App B-2: Simply supported 0.20" thick plate with pressure load
 - App B-3: Stress-free 0.02" thick plate with bulk and gradient thermal load
 - App B-4: Stress-free 0.20" thick plate with bulk and gradient thermal load

Each appendix has results for a convergence study in which the plate mesh was increased from a 2x2 mesh (for the $\frac{1}{4}$ plate) to 5x5, 10x10, 20x20, 50x50, 100x100 and finally a 200x200 mesh. In these, the elements are all square. In addition to this convergence study, the appendices also have the results of runs wherein the model with a 10x10 mesh had elements distorted (no longer square). This was done by applying a random perturbation to the grids which are interior to the plate with a successfully more severe

random coefficient. Figures 1 – 9 show the meshes for the 10x10 plate with the various distortions analyzed. As the random coefficient increased there came a time where the mesh distortion was so great that some elements had fatal errors (e.g. an interior angle of a quad element exceeded 180°).

One important finding was that the original QUAD4 Mindlin element (known internally to MYSTRAN as MIN4) has a flaw when the mesh is not rectangular. Appendices A-3 and A-4, table 4, show that with only a small distortion of the mesh from square elements, the stresses are not as close to zero as one would like. The similar results for the newer QUAD4 element (MIN4T) are shown in Appendices B-3 and B-4, table 4. As seen the stresses for the MIN4T are quite small as are those for the other plate elements (Mindlin triangle and Kirchhoff triangle and quad).

Table 1 below gives the theoretical results for the displacements and forces to compare with the tables in the appendices for the pressure load results. Equations for the theoretical results were taken from reference 1 for thin plates and from references 2 and 3 for moderately thick plates. The equations were solved in fortran programs written by the author. For the thin plate a comparison could be made for the max values of displacements and forces based on tables in reference 1 that give nondimensional coefficients for simply supported plates under a uniform pressure load. For the thick plate there were no comparison values available other than to use the thick plate equations for the thin plate. The table shows these values as well.

Table 1: Theoretical results for simply supported plate with uniform pressure load

	1	2	3	4
Max displacement or force	Kirchhoff thin plate equation solution		Mindlin thick plate equation solution	
	$t = 0.02''$	$t = 0.20''$	$t = 0.02''$	$t = 0.20''$
displacement (in)	$+4.070 \times 10^{-4}$	$+4.070 \times 10^{-7}$	$+4.072 \times 10^{-4}$	$+4.249 \times 10^{-7}$
bending moment (lb-in/in)	$+9.577 \times 10^{-3}$	$+9.577 \times 10^{-3}$	$+9.578 \times 10^{-3}$	$+9.607 \times 10^{-3}$
twisting moment (lb-in/in)	-6.496×10^{-3}	-6.496×10^{-3}	-6.493×10^{-3}	-6.225×10^{-3}
transverse shear (lb/in)	-3.375×10^{-2}	-3.375×10^{-2}	-3.376×10^{-2}	-3.374×10^{-2}

For a plate whose thickness to length (t/a) is negligible, columns 1 and 3 should be the same. The fact that they are close would seem to validate the thick plate solution programmed. Columns 1 (or 3) and 4 then would be the values to compare with the MYSTRAN QUAD4 and TRIA3 results for the 0.02'' and 0.20'' plates, respectively. Columns 1 and 2 would be the expected values from MYSTRAN for the QUAD4K and TRIA3K Kirchhoff elements for the 0.02'' and 0.20'' plates, respectively.

Table 2 gives the results for the stress free thermal loadings. Note that the displacements are the same for the thin or thick plate.

Table 2: Theoretical results for simply supported plate with stress free thermal expansion

	1	2
Max displacement or force	1.0 deg bulk temp change (all plate thicknesses)	1.0 deg temp gradient (all plate thicknesses)
displacement (in)	2.0×10^{-5}	-2.0×10^{-5}
bending moment (lb-in/in)	0	0
twisting moment (lb-in/in)	0	0
transverse shear (lb/in)	0	0

References

1. "Theory of plates and shells", S. Timoshenko
2. "On bending of elastic plates", Eric Reissner, Quarterly of Applied Mathematics, Vol V, 1947, pp 55-68
3. "Effect of shear deformations on the bending of elastic plates", V. Salerno and M. Goldberg, J of Applied Mathematics, Transactions of the ASME, March 1960, pp 54-58

Figure 1
AQ3U2S010 – Plate with no element random distortion

V1
L2
C1

10001	10002	10003	10004	10005	10006	10007	10008	10009	10010
9001	9002	9003	9004	9005	9006	9007	9008	9009	9010
8001	8002	8003	8004	8005	8006	8007	8008	8009	8010
7001	7002	7003	7004	7005	7006	7007	7008	7009	7010
6001	6002	6003	6004	6005	6006	6007	6008	6009	6010
5001	5002	5003	5004	5005	5006	5007	5008	5009	5010
4001	4002	4003	4004	4005	4006	4007	4008	4009	4010
3001	3002	3003	3004	3005	3006	3007	3008	3009	3010
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1001	1002	1003	1004	1005	1006	1007	1008	1009	1010

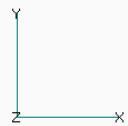


Figure 2
AQ3R2S010a – Plate with random grid disorder coefficient = 0.1

V1
L2
C1

10001	10002	10003	10004	10005	10006	10007	10008	10009	10010
9001	9002	9003	9004	9005	9006	9007	9008	9009	9010
8001	8002	8003	8004	8005	8006	8007	8008	8009	8010
7001	7002	7003	7004	7005	7006	7007	7008	7009	7010
6001	6002	6003	6004	6005	6006	6007	6008	6009	6010
5001	5002	5003	5004	5005	5006	5007	5008	5009	5010
4001	4002	4003	4004	4005	4006	4007	4008	4009	4010
3001	3002	3003	3004	3005	3006	3007	3008	3009	3010
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1001	1002	1003	1004	1005	1006	1007	1008	1009	1010

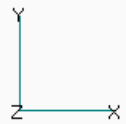


Figure 3
AQ3R2S010b – Plate with random grid disorder coefficient = 0.2

V1
L2
C1

10001	10002	10003	10004	10005	10006	10007	10008	10009	10010
9001	9002	9003	9004	9005	9006	9007	9008	9009	9010
8001	8002	8003	8004	8005	8006	8007	8008	8009	8010
7001	7002	7003	7004	7005	7006	7007	7008	7009	7010
6001	6002	6003	6004	6005	6006	6007	6008	6009	6010
5001	5002	5003	5004	5005	5006	5007	5008	5009	5010
4001	4002	4003	4004	4005	4006	4007	4008	4009	4010
3001	3002	3003	3004	3005	3006	3007	3008	3009	3010
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1001	1002	1003	1004	1005	1006	1007	1008	1009	1010

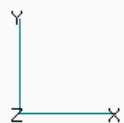


Figure 4
AQ3R2S010c – Plate with random grid disorder coefficient = 0.3

V1
L2
C1

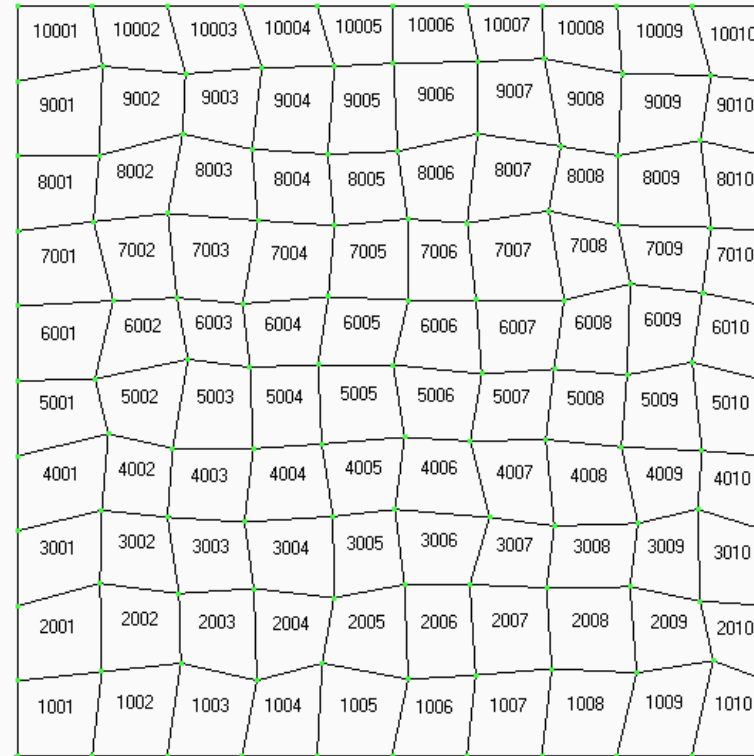
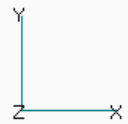


Figure 5
AQ3R2S010d – Plate with random grid disorder coefficient = 0.4

V1
L2
C1

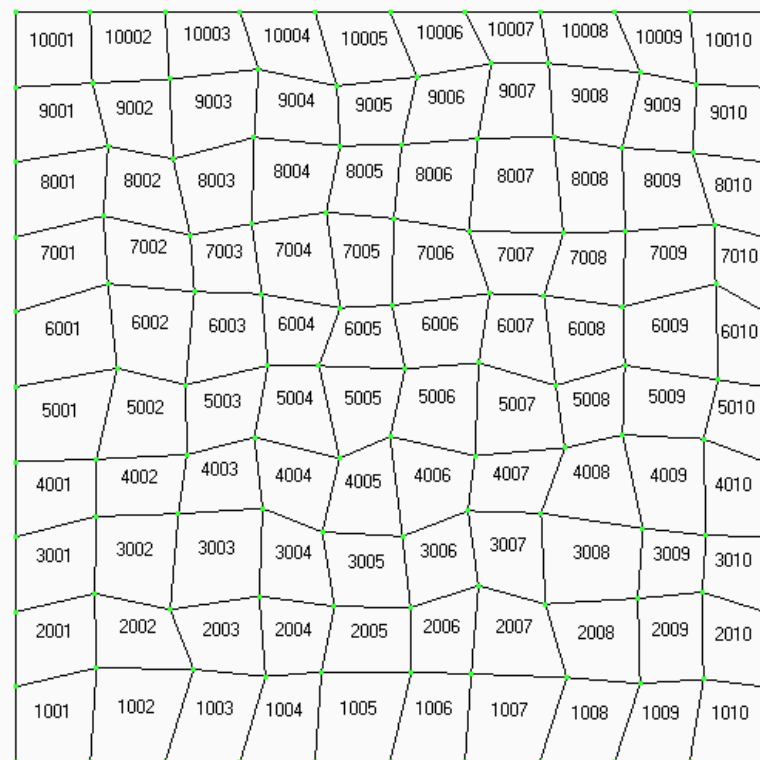
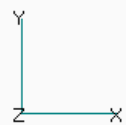


Figure 6
AQ3R2S010e – Plate with random grid disorder coefficient = 0.5

V1
L2
C1

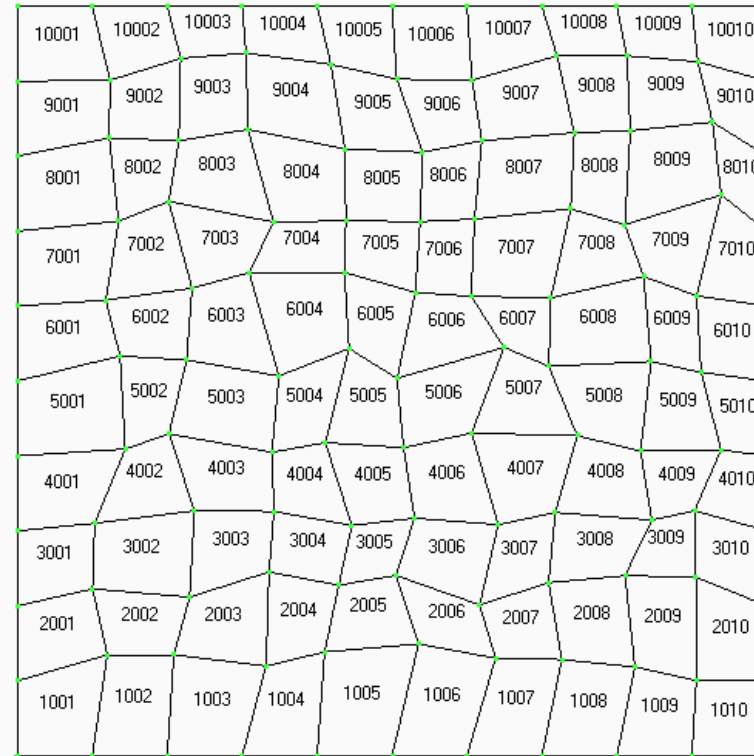
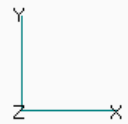


Figure 7
AQ3R2S010f – Plate with random grid disorder coefficient = 0.6

V1
L2
C1

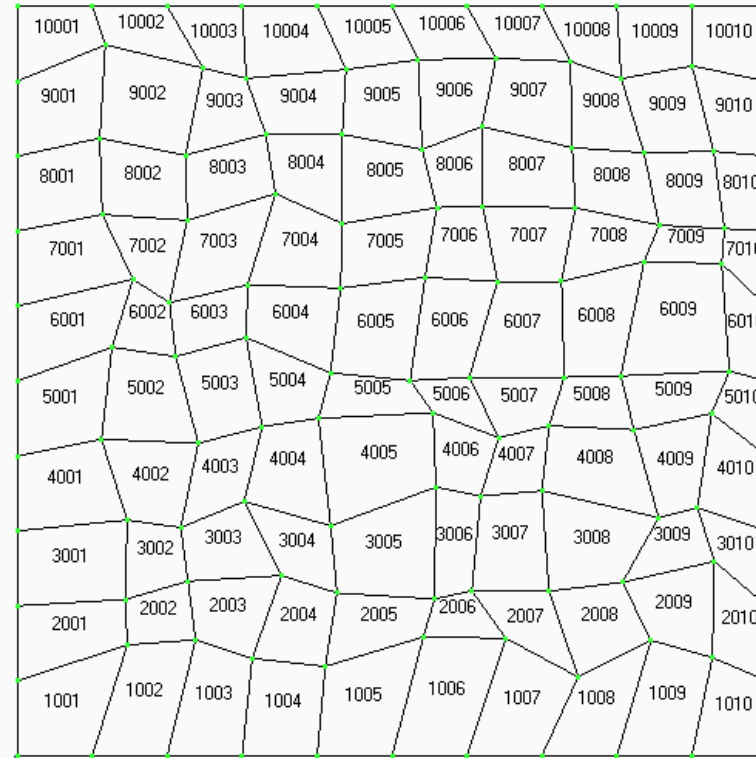
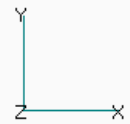


Figure 8
AQ3R2S010g – Plate with random grid disorder coefficient = 0.7

V1
L2
C1

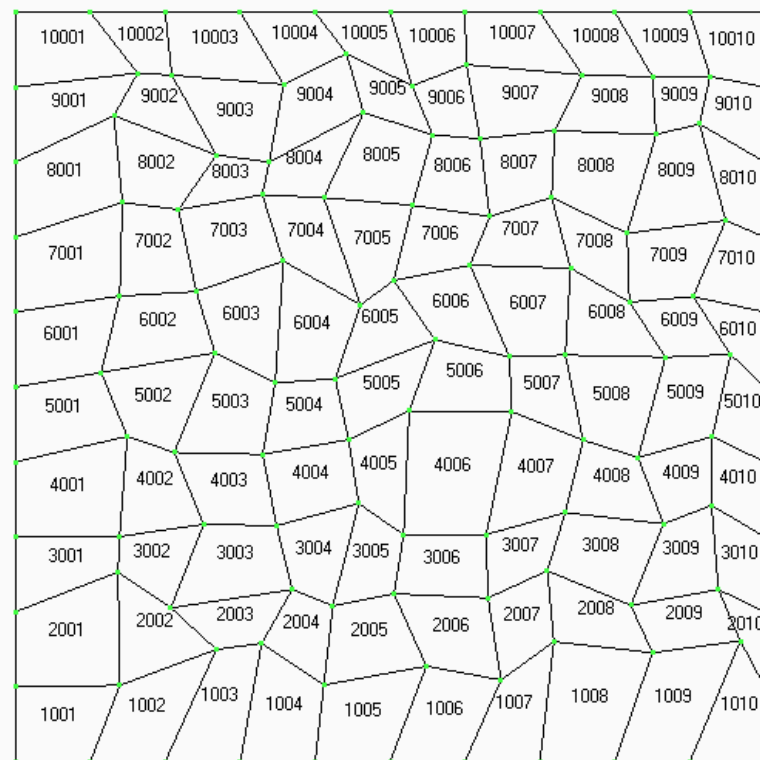
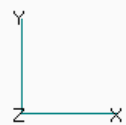
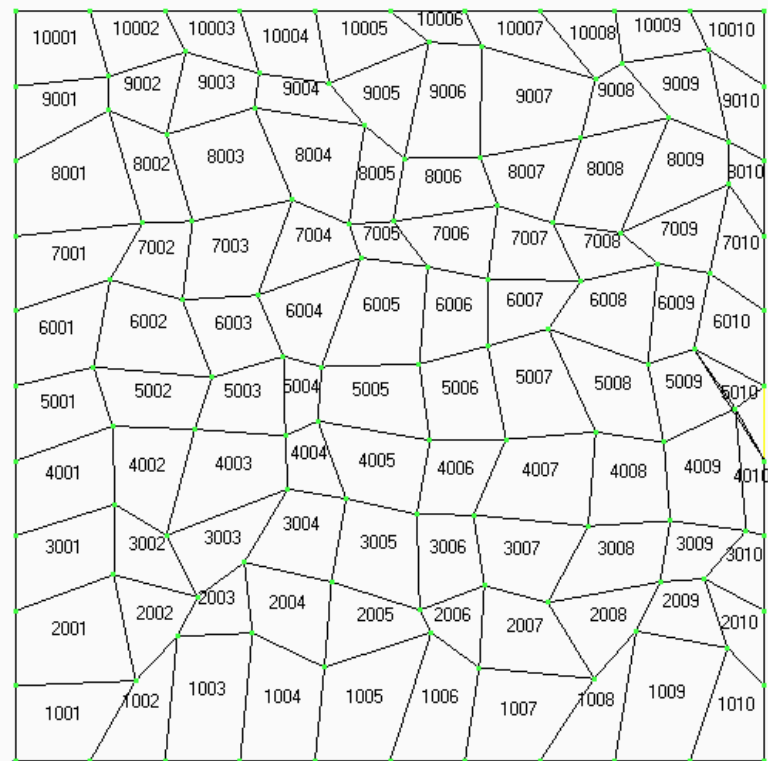
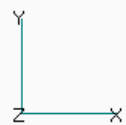


Figure 9
AQ3R2S010h – Plate with random grid disorder coefficient = 0.8

V1
L2
C1



Appendix A-1

**Simply supported square plate. 1/4 sym. Plate overall dimensions 2" X 2"
QUAD4 is MIN4 element**

Plate thickness 0.02" (thin)

Table A1-1

**Convergence study - increasing mesh size
Thin plate: 0.02" using MIN4 quad elements
Uniform pressure load 0.05 psi**

Central point lateral displacement (in)

Mesh	QUAD4 (MIM4) (AQ3U1Sxxx)	TRIA3 (AT3U1Sxxx)	QUAD4K (AQ2U1Sxxx)	TRIA3K (AT2U1Sxxx)
2	4.188881E-04	3.882019E-04	4.053825E-04	4.064101E-04
5	4.092078E-04	4.044364E-04	4.069221E-04	4.072906E-04
10	4.077716E-04	4.066298E-04	4.070296E-04	4.071537E-04
20	4.074049E-04	4.071399E-04	4.070529E-04	4.070879E-04
50	4.072946E-04	4.072582E-04	4.070591E-04	4.070651E-04
100	4.072773E-04	4.072688E-04	4.070600E-04	4.070615E-04
200	4.072728E-04	4.072707E-04	4.070602E-04	4.070605E-04

Max M_x or M_y bending moment (lb-in/in)

Mesh	QUAD4 (MIN4) (AQ3U1Sxxx)	TRIA3 (AT3U1Sxxx)	QUAD4K (AQ2U1Sxxx)	TRIA3K (AT2U1Sxxx)
2	-8.298327E-03	-8.251984E-03	-7.932362E-03	-7.980317E-03
5	-9.376329E-03	-9.402860E-03	-9.316309E-03	-9.326607E-03
10	-9.528890E-03	-9.538238E-03	-9.513549E-03	-9.514432E-03
20	-9.566863E-03	-9.568613E-03	-9.562834E-03	-9.562405E-03
50	-9.577319E-03	-9.577013E-03	-9.576632E-03	-9.576411E-03
100	-9.578778E-03	-9.578567E-03	-9.578603E-03	-9.578518E-03
200	-9.579139E-03	-9.579062E-03	-9.579095E-03	-9.579065E-03

Max M_{xy} twisting moment (lb-in/in)

Mesh	QUAD4 (MIN4) (AQ3U1Sxxx)	TRIA3 (AT3U1Sxxx)	QUAD4K (AQ2U1Sxxx)	TRIA3K (AT2U1Sxxx)
2	4.791267E-03	4.423924E-03	4.823450E-03	4.763773E-03
5	6.074485E-03	6.069230E-03	6.075395E-03	6.067006E-03
10	6.361276E-03	6.381598E-03	6.360069E-03	6.360019E-03
20	6.454034E-03	6.466028E-03	6.453200E-03	6.454149E-03
50	6.486215E-03	6.489589E-03	6.485967E-03	6.486422E-03
100	6.491816E-03	6.492906E-03	6.491745E-03	6.491934E-03
200	6.493429E-03	6.493751E-03	6.493411E-03	6.493480E-03

Max V_x or V_y transverse shear force (lb/in)

Mesh	QUAD4 (MIN4) (AQ3U1Sxxx)	TRIA3 (AT3U1Sxxx)
2	-2.197407E-02	-2.355221E-02
5	-2.886149E-02	-2.980993E-02
10	-3.128842E-02	-3.210377E-02
20	-3.252104E-02	-3.310807E-02
50	-3.326685E-02	-3.343383E-02
100	-3.351638E-02	-3.356282E-02
200	-3.364128E-02	-3.366052E-02

Table A1-2

**Random disorder of element shape - mesh size is 10 x 10
Thin plate: 0.02" using MIN4 quad elements
Uniform pressure load 0.05 psi**

Central point lateral displacement (in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R1S010)	TRIA3 (AT3R1S010)	QUAD4K (AQ2R1S010)	TRIA3K (AT2R1S010)
.0	4.077716E-04	4.066298E-04	4.070296E-04	4.071537E-04
.1	4.077502E-04	4.065895E-04	4.069936E-04	4.070827E-04
.2	4.076948E-04	4.065019E-04	4.069458E-04	4.069921E-04
.3	4.076048E-04	4.063725E-04	4.068937E-04	4.069003E-04
.4	4.073618E-04	4.062242E-04	4.068626E-04	4.067432E-04
.5	4.069259E-04	4.059689E-04	4.067344E-04	4.066651E-04
.6	4.065474E-04	4.053971E-04	4.066827E-04	4.066200E-04
.7	See Note 1	4.052982E-04	See Note 1	4.063957E-04
.8	See Note 1	4.046979E-04	See Note 1	4.062411E-04

Max M_x or M_y bending moment (lb-in/in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R1S010)	TRIA3 (AT3R1S010)	QUAD4K (AQ2R1S010)	TRIA3K (AT2R1S010)
.0	-9.528890E-03	-9.538238E-03	-9.513549E-03	-9.514432E-03
.1	-9.518489E-03	-9.531171E-03	-9.511662E-03	-9.508362E-03
.2	-9.526729E-03	-9.540563E-03	-9.497620E-03	-9.497151E-03
.3	-9.515448E-03	-9.528532E-03	-9.509454E-03	-9.505900E-03
.4	-9.526196E-03	-9.518584E-03	-9.488904E-03	-9.480915E-03
.5	-9.499431E-03	-9.503319E-03	-9.471925E-03	-9.481681E-03
.6	-9.503035E-03	-9.467728E-03	-9.462858E-03	-9.453775E-03
.7	See Note 1	-9.503531E-03	See Note 1	-9.486368E-03
.8	See Note 1	-9.454101E-03	See Note 1	-9.485915E-03

Max M_{xy} twisting moment (lb-in/in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R1S010)	TRIA3 (AT3R1S010)	QUAD4K (AQ2R1S010)	TRIA3K (AT2R1S010)
.0	6.361276E-03	6.381598E-03	6.360069E-03	6.360019E-03
.1	6.368621E-03	6.378455E-03	6.361073E-03	6.361410E-03
.2	6.364122E-03	6.390043E-03	6.370030E-03	6.377284E-03
.3	6.321933E-03	6.420099E-03	6.359695E-03	6.375967E-03
.4	6.360112E-03	6.463871E-03	6.340293E-03	6.381823E-03
.5	6.374931E-03	6.409916E-03	6.366337E-03	6.401488E-03
.6	6.211167E-03	6.496164E-03	6.357278E-03	6.390720E-03
.7	See Note 1	6.462622E-03	See Note 1	6.371801E-03
.8	See Note 1	6.719344E-03	See Note 1	6.332287E-03

MaxV_x or V_y transverse shear force (lb/in)

Random Grid Disorder	QUAD4 (MIN4) (AQ2R1S010)	TRIA3 (AT3R1S010)
.0	-3.128842E-02	-3.210377E-02
.1	-3.137333E-02	-3.249074E-02
.2	-3.126812E-02	-3.328399E-02
.3	-3.152239E-02	-3.352161E-02
.4	-3.190008E-02	-3.592427E-02
.5	-3.187843E-02	-3.431050E-02
.6	-3.305208E-02	-3.296402E-02
.7	See Note 1	-3.407969E-02
.8	See Note 1	-3.609102E-02

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Appendix A-2

**Simply supported square plate. 1/4 sym. Plate overall dimensions 2" X 2"
QUAD4 is MIN4 element**

Plate thickness 0.20" (thick)

Table A2-1

**Convergence study - increasing mesh size
Thick plate: 0.20" using MIN4 quad elements
Uniform pressure load 0.05 psi**

Central point lateral displacement (in)

Mesh	QUAD4 (MIM4) (AQ3US2xxx)	TRIA3 (AT3US2xxx)	QUAD4K (AQ2US2xxx)	TRIA3K (AT2US2xxx)
2	4.425585E-07	4.146006E-07	4.053825E-04	4.064101E-07
5	4.306603E-07	4.270713E-07	4.069221E-04	4.072906E-07
10	4.287975E-07	4.280076E-07	4.070296E-04	4.071537E-07
20	4.283199E-07	4.281360E-07	4.070529E-04	4.070879E-07
50	4.281852E-07	4.281575E-07	4.070591E-04	4.070651E-07
100	4.281659E-07	4.281593E-07	4.070600E-04	4.070615E-07
200	4.281611E-07	4.281595E-07	4.070602E-07	4.070606E-07

Max M_x or M_y bending moment (lb-in/in)

Mesh	QUAD4 (MIN4) (AQ3US2xxx)	TRIA3 (AT3US2xxx)	QUAD4K (AQ2US2xxx)	TRIA3K (AT2US2xxx)
2	-8.327611E-03	-8.286672E-03	-7.932362E-03	-7.980317E-03
5	-9.385025E-03	-9.384681E-03	-9.316309E-03	-9.326607E-03
10	-9.531068E-03	-9.522622E-03	-9.513549E-03	-9.514432E-03
20	-9.567238E-03	-9.562965E-03	-9.562834E-03	-9.562405E-03
50	-9.577337E-03	-9.576334E-03	-9.576632E-03	-9.576411E-03
100	-9.578779E-03	-9.578481E-03	-9.578603E-03	-9.578518E-03
200	-9.579140E-03	-9.579054E-03	-9.579094E-03	-9.579056E-03

Max M_{xy} twisting moment (lb-in/in)

Mesh	QUAD4 (MIN4) (AQ3US2xxx)	TRIA3 (AT3US2xxx)	QUAD4K (AQ2US2xxx)	TRIA3K (AT2US2xxx)
2	4.813814E-03	4.500427E-03	4.823450E-03	4.763773E-03
5	6.080656E-03	6.089201E-03	6.075395E-03	6.067006E-03
10	6.361956E-03	6.379003E-03	6.360069E-03	6.360019E-03
20	6.453592E-03	6.461321E-03	6.453200E-03	6.454149E-03
50	6.486000E-03	6.487857E-03	6.485967E-03	6.486422E-03
100	6.491767E-03	6.492338E-03	6.491745E-03	6.491934E-03
200	6.493441E-03	6.493610E-03	6.493411E-03	6.493481E-03

Max V_x or V_y transverse shear force (lb/in)

Mesh	QUAD4 (MIN4) (AQ3US2xxx)	TRIA3 (AT3US2xxx)
2	-2.182056E-02	-2.338886E-02
5	-2.882820E-02	-2.916144E-02
10	-3.128044E-02	-3.133337E-02
20	-3.251968E-02	-3.252939E-02
50	-3.326676E-02	-3.327051E-02
100	-3.351635E-02	-3.351810E-02
200	-3.364124E-02	-3.364134E-02

Table A2-2
Random disorder of element shape - mesh size is 10 x 10
Thick plate: 0.20" using MIN4 quad elements
Uniform pressure load 0.05 psi

Central point lateral displacement (in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R2S010)	TRIA3 (AT3R2S010)	QUAD4K (AQ2R2S010)	TRIA3K (AR2R2S010)
.0	4.287975E-07	4.280076E-07	4.070296E-04	4.071537E-07
.1	4.287897E-07	4.279977E-07	4.069889E-07	4.070835E-07
.2	4.287657E-07	4.279538E-07	4.069567E-07	4.069980E-07
.3	4.287153E-07	4.278728E-07	4.069297E-07	4.069015E-07
.4	4.286709E-07	4.277729E-07	4.068571E-07	4.067849E-07
.5	4.285825E-07	4.277427E-07	4.066887E-07	4.067714E-07
.6	4.284095E-07	4.274602E-07	See Note 1	4.066252E-07
.7	4.282386E-07	4.272412E-07	4.063414E-07	4.063621E-07
.8	See Note 1	4.273250E-07	See Note 1	4.062954E-07

Max M_x or M_y bending moment (lb-in/in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R2S010)	TRIA3 (AT3R2S010)	QUAD4K (AQ2R2S010)	TRIA3K (AR2R2S010)
.0	-9.531068E-03	-9.522622E-03	-9.513549E-03	-9.514432E-03
.1	-9.526352E-03	-9.516944E-03	-9.508573E-03	-9.509657E-03
.2	-9.525470E-03	-9.513496E-03	-9.500159E-03	-9.497733E-03
.3	-9.515931E-03	-9.510518E-03	-9.497190E-03	-9.498315E-03
.4	-9.517207E-03	-9.502445E-03	-9.492558E-03	-9.484133E-03
.5	-9.500221E-03	-9.499946E-03	-9.468693E-03	-9.478471E-03
.6	-9.473250E-03	-9.482645E-03	See Note 1	-9.475569E-03
.7	-9.525772E-03	-9.482962E-03	-9.479518E-03	-9.450705E-03
.8	See Note 1	-9.488444E-03	See Note 1	-9.472364E-03

Max M_{xy} twisting moment (lb-in/in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R2S010)	TRIA3 (AT3R2S010)	QUAD4K (AQ2R2S010)	TRIA3K (AR2R2S010)
.0	6.361956E-03	6.379003E-03	6.360069E-03	6.360019E-03
.1	6.368551E-03	6.386316E-03	6.363487E-03	6.360086E-03
.2	6.392715E-03	6.398629E-03	6.367205E-03	6.367530E-03
.3	6.346974E-03	6.390431E-03	6.347635E-03	6.389979E-03
.4	6.365845E-03	6.433151E-03	6.361833E-03	6.356812E-03
.5	6.350245E-03	6.424353E-03	6.375497E-03	6.376842E-03
.6	6.330921E-03	6.421069E-03	See Note 1	6.386909E-03
.7	6.379596E-03	6.419936E-03	6.329188E-03	6.416808E-03
.8	See Note 1	6.458207E-03	See Note 1	6.414755E-03

Max V_x or V_y transverse shear force (lb/in)

Random Grid Disorder	QUAD4 (MIN4) (AQ3R2S010)	TRIA3 (AT3R2S010)
.0	-3.128044E-02	-3.133337E-02
.1	-3.133322E-02	-3.132976E-02
.2	-3.135833E-02	-3.136309E-02
.3	-3.123436E-02	-3.139836E-02
.4	-3.131467E-02	-3.125302E-02
.5	-3.119922E-02	-3.130338E-02
.6	-3.099358E-02	-3.098793E-02
.7	-3.094443E-02	-3.154259E-02
.8	See Note 1	-3.127497E-02

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Appendix A-3

Square plate supported only at the central point. 1/4 sym.

Plate overall dimensions 2" X 2"

QUAD4 is MIN4 element

Plate thickness 0.02" (thin)

Table A3-1

Convergence study - increasing mesh size
Thin plate: 0.02” using MIN4 quad elements
Stress free thermal expansion – 1.0 deg bulk temperature change

Central point lateral displacement (in)

Mesh	QUAD4 (MIM4) (BQ3U1Fxxx)	TRIA3 (BT3U1Fxxx)	QUAD4K (BQ2U1Fxxx)	TRIA3K (BT2U1Fxxx)
2	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
5	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
10	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
20	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
50	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
100	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
200	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05

Max stress (lb/in²)

Mesh	QUAD4 (MIN4) (BQ3U1Fxxx)	TRIA3 (BT3U1Fxxx)	QUAD4K (BQ2U1Fxxx)	TRIA3K (BT2U1Fxxx)
2	E-13	E-13	E-13	E-13
5	E-13	E-12	E-12	E-12
10	E-12	E-12	E-12	E-12
20	E-12	E-12	E-12	E-12
50	E-11	E-11	E-11	E-11
100	E-10	E-10	E-10	E-10
200	E-09	E-10	E-09	E-10

Table A3-2

Random disorder of element shape - mesh size is 10 x 10
Thin plate: 0.02" using MIN4 quad elements
Stress free thermal expansion – 1.0 deg bulk temperature change

Central point lateral displacement (in)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R1F010)	TRIA3 (BT3R1F010)	QUAD4K (BQ2R1F010)	TRIA3K (BT2R1F010)
.0	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.1	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.2	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.3	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.4	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.5	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.6	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.7	2.000000E-05	2.000000E-05	See Note 1	2.000000E-05
.8	See Note 1	2.000000E-05	See Note 1	2.000000E-05

Max stress (lb/in²)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R1F010)	TRIA3 (BT3R1F010)	QUAD4K (BQ2R1F010)	TRIA3K (BT2R1F010)
.0	E-12	E-12	E-12	E-12
.1	E-11	E-12	E-12	E-12
.2	E-11	E-12	E-12	E-12
.3	E-11	E-12	E-12	E-12
.4	E-11	E-12	E-12	E-12
.5	E-11	E-12	E-12	E-12
.6	E-11	E-12	E-11	E-12
.7	E-11	E-12	See Note 1	E-12
.8	See Note 1	E-12	See Note 1	E-11

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table A3-3

Convergence study - increasing mesh size
Thin plate: 0.02” using MIN4 quad elements
Stress free thermal expansion – 1.0 deg temperature gradient through thickness

Central point lateral displacement (in)

Mesh	QUAD4 (MIM4) (BQ3U1Fxxx)	TRIA3 (BT3U1Fxxx)	QUAD4K (BQ2U1Fxxx)	TRIA3K (BT2U1Fxxx)
2	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
5	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
10	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
20	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
50	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
100	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
200	-2.000000E-05	-2.000000E-05	-2.000000E-05	-1.999998E-05

Max stress (lb/in²)

Mesh	QUAD4 (MIN4) (BQ3U1Fxxx)	TRIA3 (BT3U1Fxxx)	QUAD4K (BQ2U1Fxxx)	TRIA3K (BT2U1Fxxx)
2	E-13	E-13	E-14	E-14
5	E-12	E-12	E-12	E-13
10	E-11	E-11	E-11	E-12
20	E-11	E-11	E-09	E-09
50	E-09	E-08	E-08	E-08
100	E-08	E-09	E-08	E-06
200	E-08	E-08	E-06	E-05

Table A3-4

Random disorder of element shape - mesh size is 10 x 10
Thin plate: 0.02” using MIN4 quad elements
Stress free thermal expansion – 1.0 deg temperature gradient through thickness

Central point lateral displacement (in)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R1F010)	TRIA3 (BT3R1F010)	QUAD4K (BQ2R1F010)	TRIA3K (BT2R1F010)
.0	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.1	-1.999996E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.2	-1.999907E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.3	-1.999685E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.4	-1.999206E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.5	-1.998105E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.6	-1.997207E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.7	-1.993467E-05	-2.000000E-05	See Note 1	-2.000000E-05
.8	See Note 1	-2.000000E-05	See Note 1	-1.998677E-05

Max stress (lb/in²)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R1F010)	TRIA3 (BT3R1F010)	QUAD4K (BQ2R1F010)	TRIA3K (BT2R1F010)
.0	E-11	E-11	E-11	E-12
.1	E-04	E-11	E-11	E-11
.2	E-03	E-11	E-11	E-11
.3	E-02	E-11	E-11	E-11
.4	E-02	E-11	E-11	E-12
.5	E-02	E-11	E-11	E-11
.6	E-02	E-11	E-11	E-11
.7	E-02	E-11	See Note 1	E-11
.8	See Note 1	E-11	See Note 1	E-02

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Appendix A-4

Square plate supported only at the central point. 1/4 sym.

Plate overall dimensions 2" X 2"

QUAD4 is MIN4 element

Plate thickness 0.20" (thick)

Table A4-1

Convergence study - increasing mesh size
Thick plate: 0.20" using MIN4 quad elements
Stress free thermal expansion – 1.0 deg bulk temperature change

Central point lateral displacement (in)

Mesh	QUAD4 (MIM4) (BQ3U2Fxxx)	TRIA3 (BT3U2Fxxx)	QUAD4K (BQ2U2Fxxx)	TRIA3K (BT2U2Fxxx)
2	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
5	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
10	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
20	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
50	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
100	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
200	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05

Max stress (lb/in²)

Mesh	QUAD4 (MIN4) (BQ3U2Fxxx)	TRIA3 (BT3U2Fxxx)	QUAD4K (BQ2U2Fxxx)	TRIA3K (BT2U2Fxxx)
2	E-13	E-13	E-13	E-13
5	E-12	E-12	E-12	E-12
10	E-12	E-12	E-12	E-12
20	E-12	E-11	E-12	E-11
50	E-10	E-10	E-10	E-10
100	E-10	E-10	E-10	E-10
200	E-09	E-09	E-09	E-09

Table A4-2

Random disorder of element shape - mesh size is 10 x 10
Thick plate: 0.20" using MIN4 quad elements
Stress free thermal expansion – 1.0 deg bulk temperature change

Central point lateral displacement (in)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R2F010)	TRIA3 (BT3R2F010)	QUAD4K (BQ2R2F010)	TRIA3K (BT2R2F010)
.0	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.1	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.2	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.3	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.4	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.5	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.6	2.000000E-05	2.000000E-05	2.000000E-05	2.000000E-05
.7	2.000000E-05	2.000000E-05	See Note 1	2.000000E-05
.8	See Note 1	2.000000E-05	See Note 1	2.000000E-05

Max stress (lb/in²)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R2F010)	TRIA3 (BT3R2F010)	QUAD4K (BQ2R2F010)	TRIA3K (BT2R2F010)
.0	E-12	E-12	E-12	E-12
.1	E-12	E-12	E-12	E-12
.2	E-12	E-12	E-12	E-12
.3	E-12	E-12	E-12	E-12
.4	E-12	E-12	E-12	E-12
.5	E-12	E-12	E-12	E-12
.6	E-12	E-12	E-12	E-12
.7	E-12	E-12	See Note 1	E-12
.8	See Note 1	E-12	See Note 1	E-11

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table A4-3

Convergence study - increasing mesh size
Thick plate: 0.20" using MIN4 quad elements
Stress free thermal expansion – 1.0 deg temperature gradient through thickness

Central point lateral displacement (in)

Mesh	QUAD4 (MIM4) (BQ3U2Fxxx)	TRIA3 (BT3U2Fxxx)	QUAD4K (BQ2U2Fxxx)	TRIA3K (BT2U2Fxxx)
2	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
5	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
10	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
20	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
50	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
100	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
200	-2.000000E-05	-2.000000E-05	-2.000000E-05	-1.999998E-05

Max stress (lb/in²)

Mesh	QUAD4 (MIN4) (BQ3U2Fxxx)	TRIA3 (BT3U2Fxxx)	QUAD4K (BQ2U2Fxxx)	TRIA3K (BT2U2Fxxx)
2	E-13	E-13	E-13	E-13
5	E-13	E-12	E-11	E-11
10	E-11	E-11	E-10	E-11
20	E-11	E-10	E-09	E-09
50	E-10	E-10	E-07	E-07
100	E-10	E-10	E-06	E-06
200	E-09	E-09	E-04	E-05

Table A4-4

Random disorder of element shape - mesh size is 10 x 10
Thick plate: 0.20" using MIN4 quad elements
Stress free thermal expansion – 1.0 deg temperature gradient through thickness

Central point lateral displacement (in)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R2F010)	TRIA3 (BT3R2F010)	QUAD4K (BQ2R2F010)	TRIA3K (BT2R2F010)
.0	-2.000000E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.1	-1.999998E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.2	-1.999987E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.3	-1.999959E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.4	-1.999953E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.5	-1.999741E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.6	-1.999633E-05	-2.000000E-05	-2.000000E-05	-2.000000E-05
.7	-1.998706E-05	-2.000000E-05	See Note 1	-2.000000E-05
.8	See Note 1	-2.000000E-05	See Note 1	-2.000000E-05

Max stress (lb/in²)

Random Grid Disorder	QUAD4 (MIN4) (BQ3R2F010)	TRIA3 (BT3R2F010)	QUAD4K (BQ2R2F010)	TRIA3K (BT2R2F010)
.0	E-11	E-11	E-10	E-11
.1	E-04	E-11	E-10	E-10
.2	E-03	E-11	E-10	E-10
.3	E-03	E-12	E-10	E-11
.4	E-03	E-12	E-10	E-10
.5	E-02	E-11	E-10	E-10
.6	E-02	E-11	E-10	E-10
.7	E-01	E-11	See Note 1	E-10
.8	See Note 1	E-11	See Note 1	E-10

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Appendix B-1

**Simply supported square plate. 1/4 sym. Plate overall dimensions 2" X 2"
QUAD4 is MIN4T element**

Plate thickness 0.02" (thin)

Table B1-1

Convergence study - increasing mesh size
Thin plate: 0.02", Uniform pressure load 0.05 psi

Central point lateral displacement: theoretical = 4.070E-04 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	4.177474E-04	2.6%	3.882019E-04	-4.6%	4.053825E-04	-0.4%	4.064101E-04	-0.1%
5	4.089617E-04	0.5%	4.044364E-04	-0.6%	4.069221E-04	0.0%	4.072906E-04	0.1%
10	4.076979E-04	0.2%	4.066298E-04	-0.1%	4.070296E-04	0.0%	4.071537E-04	0.0%
20	4.073804E-04	0.1%	4.071399E-04	0.0%	4.070529E-04	0.0%	4.070879E-04	0.0%
50	4.072894E-04	0.1%	4.072582E-04	0.1%	4.070591E-04	0.0%	4.070651E-04	0.0%
100	4.072759E-04	0.1%	4.072688E-04	0.1%	4.070600E-04	0.0%	4.070615E-04	0.0%
200			4.072707E-04	0.1%	4.070602E-04	0.0%	4.070605E-04	0.0%

Max x or y bending moment: theoretical = -9.577E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-8.041848E-03	-16.0%	-8.251984E-03	-13.8%	-7.932362E-03	-17.2%	-7.980317E-03	-16.7%
5	-9.329311E-03	-2.6%	-9.402860E-03	-1.8%	-9.316309E-03	-2.7%	-9.326607E-03	-2.6%
10	-9.516958E-03	-0.6%	-9.538238E-03	-0.4%	-9.513549E-03	-0.7%	-9.514432E-03	-0.7%
20	-9.563905E-03	-0.1%	-9.568613E-03	-0.1%	-9.562834E-03	-0.1%	-9.562405E-03	-0.2%
50	-9.576865E-03	0.0%	-9.577013E-03	0.0%	-9.576632E-03	0.0%	-9.576411E-03	0.0%
100	-9.578667E-03	0.0%	-9.578567E-03	0.0%	-9.578603E-03	0.0%	-9.578518E-03	0.0%
200			-9.579062E-03	0.0%	-9.579095E-03	0.0%	-9.579065E-03	0.0%

Max twisting moment: theoretical = -6.496E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-4.642756E-03	-28.5%	-4.423924E-03	-31.9%	-4.823450E-03	-25.7%	-4.763773E-03	-26.7%
5	-6.039231E-03	-7.0%	-6.069230E-03	-6.6%	-6.075395E-03	-6.5%	-6.067006E-03	-6.6%
10	-6.350917E-03	-2.2%	-6.381598E-03	-1.8%	-6.360069E-03	-2.1%	-6.360019E-03	-2.1%
20	-6.451331E-03	-0.7%	-6.466028E-03	-0.5%	-6.453200E-03	-0.7%	-6.454149E-03	-0.6%
50	-6.485836E-03	-0.2%	-6.489589E-03	-0.1%	-6.485967E-03	-0.2%	-6.486422E-03	-0.1%
100	-6.491724E-03	-0.1%	-6.492906E-03	0.0%	-6.491745E-03	-0.1%	-6.491934E-03	-0.1%
200			-6.493751E-03	0.0%	-6.493411E-03	0.0%	-6.493480E-03	0.0%

Max x or y transverse shear: theoretical = -3.375E-02 lb/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.120397E-02	-37.2%	-2.355221E-02	-30.2%				
5	-2.873378E-02	-14.9%	-2.980993E-02	-11.7%				
10	-3.125650E-02	-7.4%	-3.210377E-02	-4.9%				
20	-3.251324E-02	-3.7%	-3.310807E-02	-1.9%				
50	-3.326562E-02	-1.4%	-3.343383E-02	-0.9%				
100	-3.351608E-02	-0.7%	-3.356282E-02	-0.6%				
200			-3.366052E-02	-0.3%				

Table B1-2

Random disorder of element shape - mesh size is 10 x 10
Thin plate: 0.02", Uniform pressure load 0.05 psi

Central point lateral displacement: theoretical = 4.070E-04 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	4.076979E-04	0.2%	4.066298E-04	-0.1%	4.070296E-04	0.0%	4.071537E-04	0.0%
0.1	4.076845E-04	0.2%	4.065895E-04	-0.1%	4.069936E-04	0.0%	4.070827E-04	0.0%
0.2	4.076601E-04	0.2%	4.065019E-04	-0.1%	4.069458E-04	0.0%	4.069921E-04	0.0%
0.3	4.076150E-04	0.2%	4.063725E-04	-0.2%	4.068937E-04	0.0%	4.069003E-04	0.0%
0.4	4.075636E-04	0.1%	4.062242E-04	-0.2%	4.068626E-04	0.0%	4.067432E-04	-0.1%
0.5	4.075042E-04	0.1%	4.059689E-04	-0.3%	4.067344E-04	-0.1%	4.066651E-04	-0.1%
0.6	4.074408E-04	0.1%	4.053971E-04	-0.4%	4.066827E-04	-0.1%	4.066200E-04	-0.1%
0.7			4.052982E-04	-0.4%			4.063957E-04	-0.1%
0.8			4.046979E-04	-0.6%			4.062411E-04	-0.2%

Max x or y bending moment: theoretical = -9.577E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-9.516958E-03	-0.6%	-9.538238E-03	-0.4%	-9.513549E-03	-0.7%	-9.514432E-03	-0.7%
0.1	-9.508684E-03	-0.7%	-9.531171E-03	-0.5%	-9.511662E-03	-0.7%	-9.508362E-03	-0.7%
0.2	-9.513518E-03	-0.7%	-9.540563E-03	-0.4%	-9.497620E-03	-0.8%	-9.497151E-03	-0.8%
0.3	-9.498255E-03	-0.8%	-9.528532E-03	-0.5%	-9.509454E-03	-0.7%	-9.505900E-03	-0.7%
0.4	-9.508094E-03	-0.7%	-9.518584E-03	-0.6%	-9.488904E-03	-0.9%	-9.480915E-03	-1.0%
0.5	-9.475692E-03	-1.1%	-9.503319E-03	-0.8%	-9.471925E-03	-1.1%	-9.481681E-03	-1.0%
0.6	-9.510552E-03	-0.7%	-9.467728E-03	-1.1%	-9.462858E-03	-1.2%	-9.453775E-03	-1.3%
0.7			-9.503531E-03	-0.8%			-9.486368E-03	-0.9%
0.8			-9.454101E-03	-1.3%			-9.485915E-03	-1.0%

Max twisting moment: theoretical = -6.496E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-6.350917E-03	-2.2%	-6.381598E-03	-1.8%	-6.360069E-03	-2.1%	-6.360019E-03	-2.1%
0.1	-6.355576E-03	-2.2%	-6.378455E-03	-1.8%	-6.361073E-03	-2.1%	-6.361410E-03	-2.1%
0.2	-6.350873E-03	-2.2%	-6.390043E-03	-1.6%	-6.370030E-03	-1.9%	-6.377284E-03	-1.8%
0.3	-6.308518E-03	-2.9%	-6.420099E-03	-1.2%	-6.359695E-03	-2.1%	-6.375967E-03	-1.8%
0.4	-6.350845E-03	-2.2%	-6.463871E-03	-0.5%	-6.340293E-03	-2.4%	-6.381823E-03	-1.8%
0.5	-6.370382E-03	-1.9%	-6.409916E-03	-1.3%	-6.366337E-03	-2.0%	-6.401488E-03	-1.5%
0.6	-6.220156E-03	-4.2%	-6.496164E-03	0.0%	-6.357278E-03	-2.1%	-6.390720E-03	-1.6%
0.7			-6.462622E-03	-0.5%			-6.371801E-03	-1.9%
0.8			-6.179344E-03	3.4%			-6.332287E-03	-2.5%

Max x or y transverse shear: theoretical = -3.375E-02 lb/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-3.125650E-02	-7.4%	-3.230785E-02	-4.3%				
0.1	-3.137727E-02	-7.0%	-3.249074E-02	-3.7%				
0.2	-3.131193E-02	-7.2%	-3.328399E-02	-1.4%				
0.3	-3.227968E-02	-4.4%	-3.352161E-02	-0.7%				
0.4	-3.253596E-02	-3.6%	-3.592427E-02	6.4%				
0.5	-3.573537E-02	5.9%	-3.431050E-02	1.7%				
0.6	-3.739516E-02	10.8%	-3.296402E-02	-2.3%				
0.7			-3.407969E-02	1.0%				
0.8			-3.609102E-02	6.9%				

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Appendix B-2

**Simply supported square plate. 1/4 sym. Plate overall dimensions 2" X 2"
QUAD4 is MIN4T element**

Plate thickness 0.20" (thick)

Table B2-1

Convergence study - increasing mesh size
Thick plate: 0.20", Uniform pressure load 0.05 psi

Central point lateral displacement: theoretical = 4.294E-07 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	4.395387E-07	2.4%	4.146006E-07	-3.4%	4.053825E-07	-5.6%	4.064101E-07	-5.4%
5	4.300534E-07	0.2%	4.270713E-07	-0.5%	4.069221E-07	-5.2%	4.072906E-07	-5.1%
10	4.286389E-07	-0.2%	4.280076E-07	-0.3%	4.070296E-07	-5.2%	4.071537E-07	-5.2%
20	4.282798E-07	-0.3%	4.281360E-07	-0.3%	4.070529E-07	-5.2%	4.070879E-07	-5.2%
50	4.281788E-07	-0.3%	4.281575E-07	-0.3%	4.070591E-07	-5.2%	4.070651E-07	-5.2%
100	4.281643E-07	-0.3%	4.281593E-07	-0.3%	4.070600E-07	-5.2%	4.070615E-07	-5.2%
200			4.281595E-07	-0.3%	4.070602E-07	-5.2%	4.070606E-07	-5.2%

Max x or y bending moment: theoretical = -9.607E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-8.074155E-03	-16.0%	-8.286672E-03	-13.7%	-7.932362E-03	-17.4%	-7.980317E-03	-16.9%
5	-9.340636E-03	-2.8%	-9.384681E-03	-2.3%	-9.316309E-03	-3.0%	-9.326607E-03	-2.9%
10	-9.520004E-03	-0.9%	-9.522622E-03	-0.9%	-9.513549E-03	-1.0%	-9.514432E-03	-1.0%
20	-9.564479E-03	-0.4%	-9.562965E-03	-0.5%	-9.562834E-03	-0.5%	-9.562405E-03	-0.5%
50	-9.576896E-03	-0.3%	-9.576334E-03	-0.3%	-9.576632E-03	-0.3%	-9.576411E-03	-0.3%
100	-9.578669E-03	-0.3%	-9.578481E-03	-0.3%	-9.578603E-03	-0.3%	-9.578518E-03	-0.3%
200			-9.579054E-03	-0.3%	-9.579094E-03	-0.3%	-9.579056E-03	-0.3%

Max twisting moment: theoretical = -6.225E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-4.668448E-03	-25.0%	-4.500427E-03	-27.7%	-4.823450E-03	-22.5%	-4.763773E-03	-23.5%
5	-6.052187E-03	-2.8%	-6.089201E-03	-2.2%	-6.075395E-03	-2.4%	-6.067006E-03	-2.5%
10	-6.354222E-03	2.1%	-6.379003E-03	2.5%	-6.360069E-03	2.2%	-6.360019E-03	2.2%
20	-6.451367E-03	3.6%	-6.461321E-03	3.8%	-6.453200E-03	3.7%	-6.454149E-03	3.7%
50	-6.485563E-03	4.2%	-6.487857E-03	4.2%	-6.485967E-03	4.2%	-6.486422E-03	4.2%
100	-6.491641E-03	4.3%	-6.492338E-03	4.3%	-6.491745E-03	4.3%	-6.491934E-03	4.3%
200			-6.493610E-03	4.3%	-6.493411E-03	4.3%	-6.493481E-03	4.3%

Max x or y transverse shear: theoretical = -3.374E-02 lb/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.112100E-02	-37.4%	-2.338886E-02	-30.7%				
5	-2.870941E-02	-14.9%	-2.916144E-02	-13.6%				
10	-3.125004E-02	-7.4%	-3.133337E-02	-7.1%				
20	-3.251203E-02	-3.6%	-3.252939E-02	-3.6%				
50	-3.326553E-02	-1.4%	-3.327051E-02	-1.4%				
100	-3.351604E-02	-0.7%	-3.351810E-02	-0.7%				
200			-3.364134E-02	-0.3%				

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table B2-2

Random disorder of element shape - mesh size is 10 x 10
Thick plate: 0.20", Uniform pressure load 0.05 psi

Central point lateral displacement: theoretical = 4.294E-07 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	4.286389E-07	-0.2%	4.280076E-07	-0.3%	4.070296E-07	-5.2%	4.071537E-07	-5.2%
0.1	4.286363E-07	-0.2%	4.279977E-07	-0.3%	4.069889E-07	-5.2%	4.070835E-07	-5.2%
0.2	4.286255E-07	-0.2%	4.279538E-07	-0.3%	4.069567E-07	-5.2%	4.069980E-07	-5.2%
0.3	4.286026E-07	-0.2%	4.278728E-07	-0.4%	4.069297E-07	-5.2%	4.069015E-07	-5.2%
0.4	4.285964E-07	-0.2%	4.277729E-07	-0.4%	4.068571E-07	-5.2%	4.067849E-07	-5.3%
0.5	4.285648E-07	-0.2%	4.277427E-07	-0.4%	4.06887E-07	-5.3%	4.067714E-07	-5.3%
0.6	4.285039E-07	-0.2%	4.274602E-07	-0.5%	See Note 1		4.066252E-07	-5.3%
0.7	4.284351E-07	-0.2%	4.272412E-07	-0.5%	4.063414E-07	-5.4%	4.063621E-07	-5.4%
0.8	See Note 1		4.273250E-07	-0.5%	See Note 1		4.062954E-07	-5.4%

Max x or y bending moment: theoretical = -9.607E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-9.520004E-03	-0.9%	-9.522622E-03	-0.9%	-9.513549E-03	-1.0%	-9.514432E-03	-1.0%
0.1	-9.516887E-03	-0.9%	-9.516944E-03	-0.9%	-9.508573E-03	-1.0%	-9.509657E-03	-1.0%
0.2	-9.515005E-03	-1.0%	-9.513496E-03	-1.0%	-9.500159E-03	-1.1%	-9.497733E-03	-1.1%
0.3	-9.510936E-03	-1.0%	-9.510518E-03	-1.0%	-9.497190E-03	-1.1%	-9.498315E-03	-1.1%
0.4	-9.503080E-03	-1.1%	-9.502445E-03	-1.1%	-9.492558E-03	-1.2%	-9.484133E-03	-1.3%
0.5	-9.495133E-03	-1.2%	-9.499946E-03	-1.1%	-9.468693E-03	-1.4%	-9.478471E-03	-1.3%
0.6	-9.485838E-03	-1.3%	-9.482645E-03	-1.3%	See Note 1		-9.475569E-03	-1.4%
0.7	-9.523367E-03	-0.9%	-9.482962E-03	-1.3%	-9.479518E-03	-1.3%	-9.450705E-03	-1.6%
0.8	See Note 1		-9.488444E-03	-1.2%	See Note 1		-9.472364E-03	-1.4%

Max twisting moment: theoretical = -6.225E-03 lb-in/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-6.354222E-03	2.1%	-6.379003E-03	2.5%	-6.360069E-03	2.2%	-6.360019E-03	2.2%
0.1	-6.358936E-03	2.2%	-6.386316E-03	2.6%	-6.363487E-03	2.2%	-6.360086E-03	2.2%
0.2	-6.377200E-03	2.4%	-6.398629E-03	2.8%	-6.367205E-03	2.3%	-6.367530E-03	2.3%
0.3	-6.335701E-03	1.8%	-6.390431E-03	2.7%	-6.347635E-03	2.0%	-6.389979E-03	2.7%
0.4	-6.359404E-03	2.2%	-6.433151E-03	3.3%	-6.361833E-03	2.2%	-6.356812E-03	2.1%
0.5	-6.337010E-03	1.8%	-6.424353E-03	3.2%	-6.375497E-03	2.4%	-6.376842E-03	2.4%
0.6	-6.323262E-03	1.6%	-6.421069E-03	3.1%	See Note 1		-6.386909E-03	2.6%
0.7	-6.361620E-03	2.2%	-6.419936E-03	3.1%	-6.329188E-03	1.7%	-6.416808E-03	3.1%
0.8	See Note 1		-6.458207E-03	3.7%	See Note 1		-6.414755E-03	3.0%

Max x or y transverse shear: theoretical = -3.375E-02 lb/in

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-3.125004E-02	-7.4%	-3.133337E-02	-7.2%				
0.1	-3.131184E-02	-7.2%	-3.132976E-02	-7.2%				
0.2	-3.129734E-02	-7.3%	-3.136309E-02	-7.1%				
0.3	-3.129752E-02	-7.3%	-3.139836E-02	-7.0%				
0.4	-3.133671E-02	-7.2%	-3.125302E-02	-7.4%				
0.5	-3.128780E-02	-7.3%	-3.130338E-02	-7.2%				
0.6	-3.120514E-02	-7.5%	-3.098793E-02	-8.2%				
0.7	-3.094243E-02	-8.3%	-3.154259E-02	-6.5%				
0.8	See Note 1		-3.127497E-02	-7.3%				

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

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Appendix B-3

Square plate supported only at the central point. 1/4 sym.

Plate overall dimensions 2" X 2"

QUAD4 is MIN4T element

Plate thickness 0.02" (thin)

Table B3-1

Convergence study - increasing mesh size
Thin plate: 0.02", stress free thermal expansion - 1.0 deg bulk temperature change

Central point lateral displacement: theoretical = 2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
10	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
20	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
50	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
100	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
200	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-13		E-13		E-13		E-13	
5	E-13		E-12		E-12		E-12	
10	E-12		E-12		E-12		E-12	
20	E-12		E-12		E-12		E-12	
50	E-11		E-11		E-11		E-11	
100	E-10		E-10		E-10		E-10	
200			E-10		E-09		E-10	

Table B3-2

Random disorder of element shape - mesh size is 10 x 10
Thin plate: 0.02", stress free thermal expansion - 1.0 deg bulk temperature change

Central point lateral displacement: theoretical = 2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.1	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.3	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.4	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.6	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.7	2.000000E-05	0.0%	2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%
0.8	See Note 1		2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-12		E-12		E-12		E-12	
0.1	E-12		E-12		E-12		E-12	
0.2	E-12		E-12		E-12		E-12	
0.3	E-12		E-12		E-12		E-12	
0.4	E-12		E-12		E-12		E-12	
0.5	E-12		E-12		E-12		E-12	
0.6	E-12		E-12		E-11		E-12	
0.7	E-12		E-12		See Note 1		E-12	
0.8	See Note 1		E-12		See Note 1		E-11	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table B3-3

Convergence study - increasing mesh size

Thin plate: 0.02", stress free thermal expansion - 1.0 deg temperature gradient through thickness

Central point lateral displacement: theoretical = -2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
10	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
20	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
50	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
100	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
200	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-1.999998E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-13		E-13		E-14		E-14	
5	E-12		E-12		E-12		E-13	
10	E-11		E-11		E-11		E-12	
20	E-10		E-11		E-09		E-09	
50	E-09		E-08		E-08		E-08	
100	E-07		E-09		E-08		E-06	
200			E-08		E-06		E-05	

Table B3-4

Random disorder of element shape - mesh size is 10 x 10

Thin plate: 0.02", stress free thermal expansion - 1.0 deg temperature gradient through thickness

Central point lateral displacement: theoretical = -2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.1	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.3	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.4	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.6	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.7	-2.000000E-05	0.0%	-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%
0.8	See Note 1		-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-11		E-11		E-11		E-12	
0.1	E-12		E-11		E-11		E-11	
0.2	E-12		E-11		E-11		E-11	
0.3	E-11		E-11		E-11		E-11	
0.4	E-11		E-11		E-11		E-12	
0.5	E-11		E-11		E-11		E-11	
0.6	E-10		E-11		E-11		E-11	
0.7	E-11		E-11		See Note 1		E-11	
0.8	See Note 1		E-11		See Note 1		E-02	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Appendix B-4

Square plate supported only at the central point. 1/4 sym.

Plate overall dimensions 2" X 2"

QUAD4 is MIN4T element

Plate thickness 0.20" (thick)

Table B4-1

Convergence study - increasing mesh size
 Thick plate: 0.20", stress free thermal expansion - 1.0 deg bulk temperature change

Central point lateral displacement: theoretical = 2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
10	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
20	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
50	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
100	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
200	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-13		E-13		E-13		E-13	
5	E-12		E-12		E-12		E-12	
10	E-11		E-12		E-12		E-12	
20	E-11		E-11		E-12		E-11	
50	E-10		E-10		E-10		E-10	
100	E-10		E-10		E-10		E-10	
200			E-09		E-09		E-09	

Table B4-2

Random disorder of element shape - mesh size is 10 x 10
 Thick plate: 0.20", stress free thermal expansion - 1.0 deg bulk temperature change

Central point lateral displacement: theoretical = 2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.1	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.2	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.3	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.4	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.5	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.6	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%	2.000000E-05	0.0%
0.7	2.000000E-05	0.0%	2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%
0.8	See Note 1		2.000000E-05	0.0%	See Note 1		2.000000E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-11		E-12		E-12		E-12	
0.1	E-12		E-12		E-12		E-12	
0.2	E-12		E-12		E-12		E-12	
0.3	E-12		E-12		E-12		E-12	
0.4	E-12		E-12		E-12		E-12	
0.5	E-12		E-12		E-12		E-12	
0.6	E-12		E-12		E-12		E-12	
0.7	E-12		E-12		See Note 1		E-12	
0.8	See Note 1		E-12		See Note 1		E-11	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)

Table B4-3

Convergence study - increasing mesh size

Thick plate: 0.20", stress free thermal expansion - 1.0 deg temperature gradient through thickness

Central point lateral displacement: theoretical = -2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
10	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
20	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
50	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
100	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
200			-2.000000E-05	0.0%	-2.000000E-05	0.0%	-1.999998E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
2	E-12		E-13		E-13		E-13	
5	E-12		E-12		E-11		E-11	
10	E-11		E-11		E-10		E-11	
20	E-11		E-10		E-09		E-09	
50	E-10		E-10		E-07		E-07	
100	E-10		E-10		E-06		E-06	
200			E-09		E-04		E-05	

Table B4-4

Random disorder of element shape - mesh size is 10 x 10

Thick plate: 0.20", stress free thermal expansion - 1.0 deg temperature gradient through thickness

Central point lateral displacement: theoretical = -2.000E-05 inches

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.1	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.2	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.3	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.4	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.5	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.6	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%	-2.000000E-05	0.0%
0.7	-2.000000E-05	0.0%	-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%
0.8	See Note 1		-2.000000E-05	0.0%	See Note 1		-2.000000E-05	0.0%

Max stress: theoretical = 0 lb/in^2

Random Grid Disorder	QUAD4 (MIN4T)		TRIA3		QUAD4K		TRIA3K	
	Displ	Error	Displ	Error	Displ	Error	Displ	Error
0	E-11		E-11		E-10		E-11	
0.1	E-11		E-11		E-10		E-10	
0.2	E-11		E-11		E-10		E-10	
0.3	E-11		E-12		E-10		E-11	
0.4	E-11		E-12		E-10		E-10	
0.5	E-11		E-11		E-10		E-10	
0.6	E-11		E-11		E-10		E-10	
0.7	E-09		E-11		See Note 1		E-10	
0.8	See Note 1		E-11		See Note 1		E-10	

Note 1: Random disorder of internal grids is so large as to cause one or more elements to have a fatal error (e.g. interior angle > 180 deg, element not numbered CW or CCW, or negative area)